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A 10 Watt Power Amplifier for the 13cm Band using GaAs Technology

Developed with the help of PUFF CAD Software

The two-stage power amplifier introduced in issue 3/1994 [1] of VHF Communications supplies an output power of 5 Watts in the 13cm band in linear operation (class A) with 23 dB amplification.

The article below introduces a new amplifier in this development range, which yields an output power of 10 Watts with a linear amplification of 20 dB.

The circuit and layout have once again been set up using Puff CAD software [4], on the basis of the results from the development work on the 5 Watt amplifier. As a result of this, a parallel circuit with two 5 Watt stages has been inserted in the high-level stage of this amplifier unit.

1. CHOICE OF SEMICONDUCTOR

The transistors used in the amplifier are Mitsubishi GaAsFETs from the 0900 range. The 0905 type is used in the driver stage. with two type 0906's in the parallel high-level stage.

The following performance data were the targets aimed for in the development work:

Amplification:	> 20 dB at K > 1
Output power:	Min. 10 W at max. 1 dB compression
Band width:	100 MHz
Zin = Zout:	= 50Ω with return loss > = 20 dB

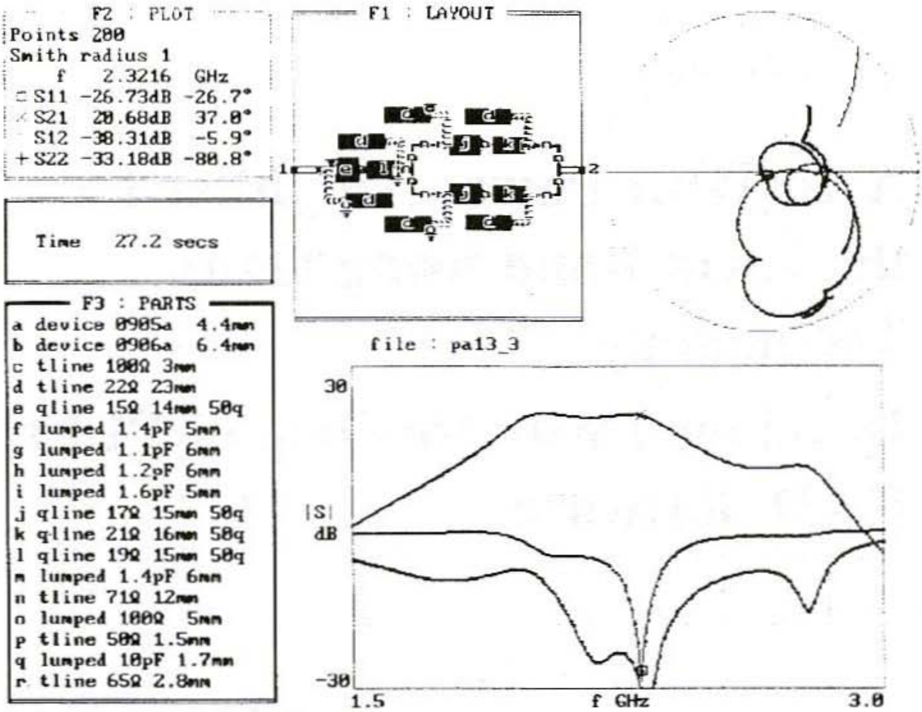


Fig.1: PUFF CAD Program Screen Print-Out

Arguments in favour of using a parallel high-level stage consisting of two 5 Watt transistors (as opposed to a single stage with a 10 Watt transistor) are the higher efficiency and the higher (in total) power loss of the parallel-switched high-level stage transistors and the, at present, rather more favourable cost/performance ratio of the 0906 GaAsFET, as against the 10 Watt 0907 type.

According to the Mitsubishi data sheet, in the given frequency range the 0906 attains an output power of 5.0 Watts = 37 dBm at Uds = 10 V, Ids = 1.1 A, with an amplification of 11 dB at 40% efficiency.

In comparison with the 0907 type (40 dBm output power / 10 dB / 37%), there is a lower power advantage in favour of the two parallel-wired 0906 stages.

The 0905 type comfortably supplies the necessary drive power of app. 1 Watt for the parallel stage with an amplification of approximately 10 dB. Its typical power is given by Mitsubishi as app. 34 dBm = 2.5 Watts at 8 V / 0.8 A.

The S-parameters for the selected transistors required for the circuit development are taken from the Mitsubishi data bank and are valid for the DC voltage conditions referred to above.

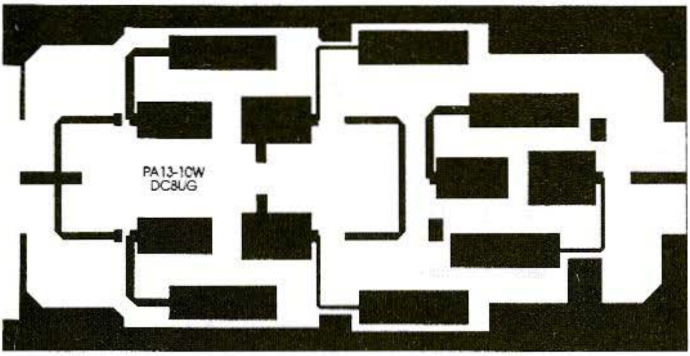


Fig.2: PCB Layout for the 10 Watt High-Level Stage

In operation, there is a DC input power exceeding 30 Watts, so the heat sink must have generous dimensions, in order to guarantee that the maximum permissible temperature for the transistors, of 175° is never reached.

2. SIMULATION AND ANALYSIS OF AMPLIFIER CIRCUIT USING CAD SOFTWARE

The functioning of the Puff CAD software is comprehensively described in [2] [3] [4], so only the results obtained are presented and analysed here. Fig.1 shows the screen print-out from Puff with the draft layout of the circuit, the associated Smith diagram, the parts list and the scatter parameter curve over the selected frequency range (1.5 - 3.0 GHz).

From the calculated scatter parameters, the stability factor, K, of the amplifier circuit can be subsequently determined for the operating frequency (2.3216 GHz) [5]. When plotted against the frequency, the gain slope obtained (S21) clearly shows the influence of the 71Ω L/4 coupler between the two high-level transistors. This type of coupling pre-supposes a transformation of all individual stages with a 50Ω impedance, and is well known from aerial engineering. It is relatively loss-free and is particularly effective when each individual stage is transformed before the hook-up on the calculator to Zin = Zout = 50Ω. The better this transformation is carried out, the "smoother" the gain slope actually obtained is, plotted against the frequency.

The calculated input impedance (S11) is more strongly dependent on the frequency than the output impedance (S22), and here the typical broadbandedness of parallel stages shows to advantage. The values shown in Fig.1 give the following performance values for the simulated circuit at an operating frequency of 2,320 MHz:

Return loss input:	- 26.7 dB
Return loss output:	- 33.2 dB
Amplification:	+ 20.7 dB
Feedback:	- 38.3 dB
K factor at 2,320 MHz:	29
Power band width (-3 db):	- 400 MHz
	+ 100 MHz

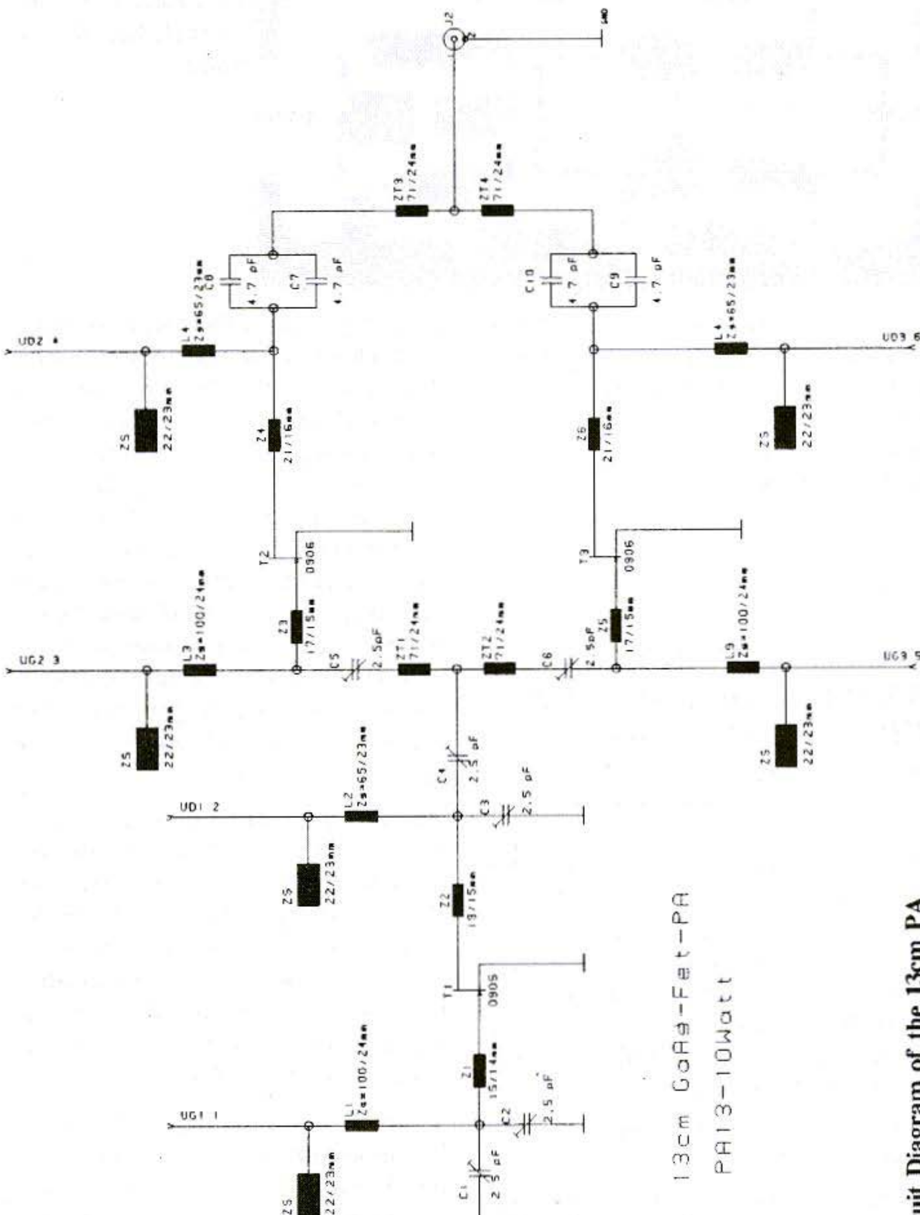


Fig.3: Circuit Diagram of the 13cm PA

C1	Trimmer	2.5pF	Teflon/Ceramic
C2	Trimmer	2.5pF	Teflon/Ceramic
C3	Trimmer	2.5pF	Teflon/Ceramic
C4	Trimmer	2.5pF	Teflon/Ceramic
C5	Trimmer	2.5pF	Teflon/Ceramic
C6	Trimmer	2.5pF	Teflon/Ceramic
C7	Capacitor	4.7pF	ATC-Chip 100
C8	Capacitor	4.7pF	ATC-Chip 100
C9	Capacitor	4.7pF	ATC-Chip 100
C10	Capacitor	4.7pF	ATC-Chip 100
J1	Socket	N-type or SMA	
J2	Socket	N-type or SMA	
L1	Inductor	100/24mm Stripline	
L2	Inductor	65/23mm Stripline	
L3	Inductor	100/24mm Stripline	
L4	Inductor	65/23mm Stripline	
L5	Inductor	100/24mm Stripline	
L6	Inductor	65/23mm Stripline	
T1	FET	0905	Mitsubishi
T2	FET	0906	Mitsubishi
T3	FET	0906	Mitsubishi
ZS	Inductor	22/23mm Stripline	
Z1	Inductor	15/14mm Stripline	
Z2	Inductor	19/15mm Stripline	
Z3	Inductor	17/15mm Stripline	
Z4	Inductor	21/16mm Stripline	
Z5	Inductor	17/15mm Stripline	
Z6	Inductor	21/16mm Stripline	
ZT1-ZT4	Inductor	71/24mm Stripline	

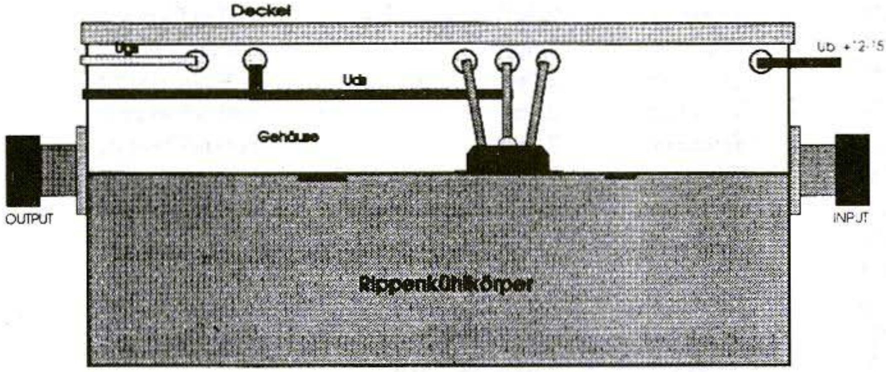
Fig.4: Parts List for the 13cm 10W PA

Fig.2 shows the layout generated by the CAD software as a laser print-out, for Teflon-based material with a substrate thickness of 0.79 mm..

The earth paths on the longitudinal and transverse sides of the boards are surfaces which are added later and which are through-hole plated to the underside of the boards.

In the parts list in Fig.1, we can also recognise the necessary discrete components of the circuit, under the description "lumped". Here we are dealing with capacitors and resistances which are necessary for the circuit to operate.

Fig.3 shows the wiring diagram for the 10 Watt parallel high-level stage. Fig.4 shows all components required in the parts list.



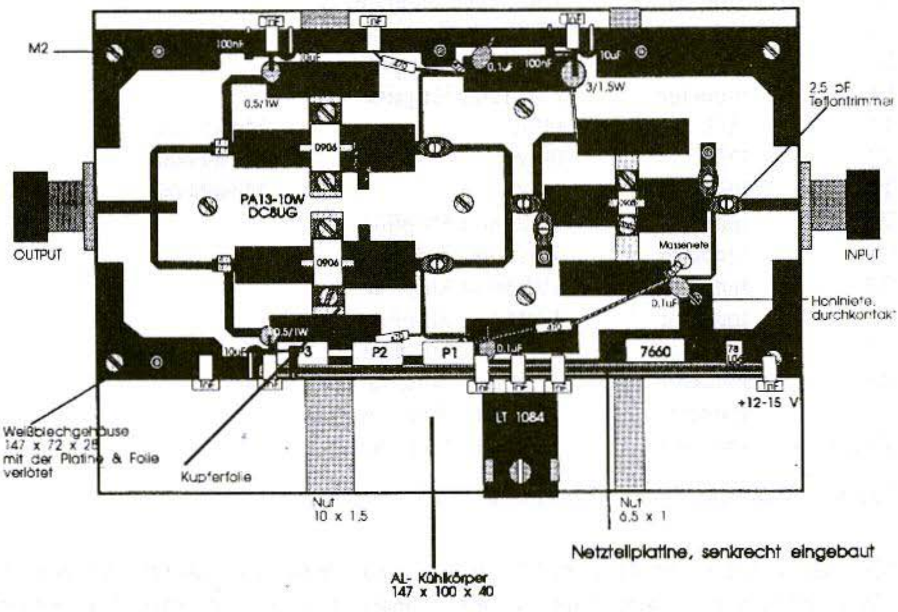


Fig.5a: Side View of a finished unit **Fig.5b: Component Layout**

Deckel **= Cover; Gehäuse = Cover;** ***Rippenkülkörper*** **= Finned Cooling Body;**
Mit der Platine & Folie Verlötet **= Soldered to Board and Foil;**
Weißblechgehäuse **= Tinplate Housing;** ***Kupferfolie*** **= Copper Foil;**
Nut **= groove;** ***Masseniete*** **= Solid Rivets;** ***Kühlkörper*** **= Cooling Body;**
Hohlniete, durchkontaktiert **= Hollow rivet, through-hole plated;**
Netzteilplatine, senkrecht eingebaut **= PSU board, vertically inserted**

3. AMPLIFIER ASSEMBLY

The amplifier circuit is assembled on a Teflon board (er = 2.33) with the dimensions 146 mm. x 72 mm. x 0.79 mm.. For its part, it is screwed to an aluminium finned cooling body with dimensions of 147 mm. x 100 mm. x 40 mm., which acts as a fastening and a heat sink for the power transistors and voltage regulator (Fig.5a).

The DC voltage supply is mounted on a double-coated epoxy board, measuring 105 mm. x 20 mm. x 1.6 mm., internally soldered vertically to the longitudinal side of the housing (Fig.5b). Its circuit and structure correspond to the publications as per [6] or [1].

Fig.6 shows the wiring diagram, Fig.7 the components diagram, and Fig.8 the parts list for this power supply. The components are all mounted on the foil side, so that the earth surfaces have to be through-hole plated.

Grooves are milled in the cooling body, so that the drain and gate connections of the transistors can be soldered as flat as possible to the board. The grooves are laid out a little wide, to give a greater tolerance in the mounting of the transistors.

The Teflon board has a recess of 4.5 mm. x 17 mm. and two recesses of 6.5 mm. x 22 mm., into which the transistors are inserted and then screwed to the cooling body (see Fig.5). Between the board and the cooling body, there is also some copper foil (dimensions 148 mm. x 73 mm. x 0.08 mm.), which is later soldered to the tinplate housing. It improves the earth connection between the transistors, the board, the housing and the cooling body.

Before the board is installed, the earth surfaces must be through-hole plated using 2-mm. diameter hollow copper rivets. Here there should be 3 or 4 rivets per longitudinal side and 1 or 2 rivets per earth link (see Fig.5). The board is fastened to the cooling body by means of 8 M2 screws. The transistors need 2 threaded holes each in the baseplate for the source connection.

The tinplate housing (147 mm. x 72 mm. x 28 mm.) is provided with the appropriate holes and recesses before assembly. The housing is soldered together and soldered to the screwed-on board on the longitudinal sides. The soldered-on sockets are also screwed into the front faces of the cooling body.

The best approach is to assemble the components and bring them into operation in the following sequence:

- Assemble and incorporate the power supply board. The gate resistances (R4, R5) should already be soldered to the power supply for a better assembly!

Tip: *To avoid regenerative feedback, the gate power supply connection for the transistor, T3, through the resistance, R6, may not go straight across the board, but must be taken round outside, like the drain power supply (see Fig.5).*

- Install and wire up the 8 feedthrough capacitors (1 nF) and the blocking capacitors, C9 - C15, C17, C19.

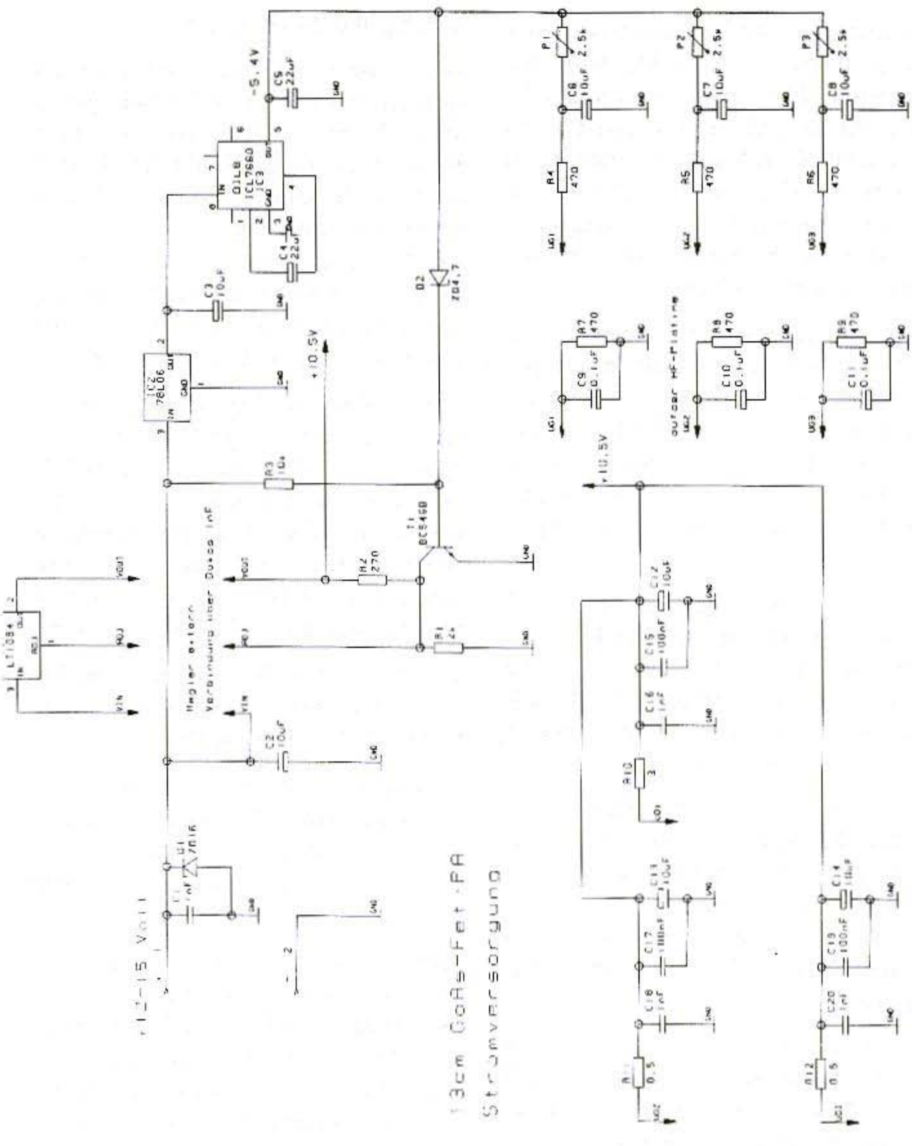


Fig.6: Circuit Diagram of the PSU

- Insulated fastening and connecting of voltage regulator using feedthrough capacitors.
- Install and connect resistances (R7, R8, R9, R11, R12) on and to high-frequency board.
- Install trimmers (C1 - C6)

Tip: *Ceramic trimmers of the Johanson 0.5 - 2.5 pF type are more suitable than Teflon trimmers, as they still give stable capacity values, even after repeated calibrations!*

- Install chip capacitors (C7 - C10)

Tip: *You should definitely use the very low loss ATC 100 porcelain type from Johanson.*

- De-bugging the power supply (UG and UD)
- Install GaAsFETs
- Set zero signal currents: 0905 - ID = 0.8A; 0906 - ID = 1.1A

4. READINGS

After calibration at 2,320 MHz, the prototype attained an output power of 11 Watts with a driving power of 120 mW. The measurement was carried out using an HP 432B Wattmeter and a 30 dB + 10 dB attenuator from Narda.

Fig.9 shows the amplifier's transfer characteristic. The compression area begins at an output power level of approximately 10.5 Watts - i.e. any

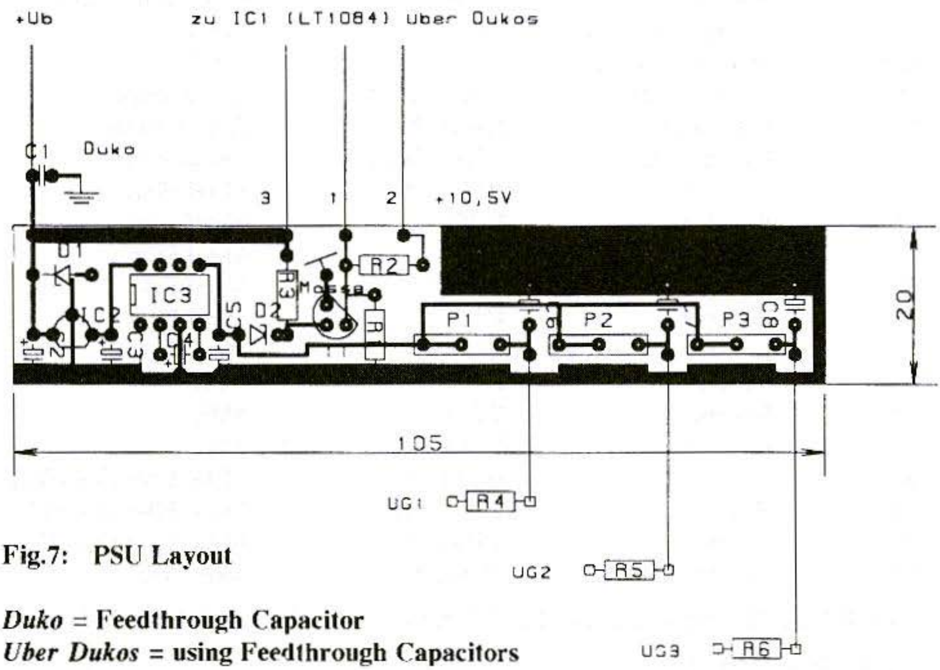


Fig.7: PSU Layout

Duko **= Feedthrough Capacitor**
Uber Dukos **= using Feedthrough Capacitors**

C1	Capacitor	1nF	Feed-Through
C2	Capacitor	10µF	Tantalum 16V
C3	Capacitor	10µF	Tantalum 16V
C4	Capacitor	22µF	Tantalum 10V
C5	Capacitor	22µF	Tantalum 10V
C6	Capacitor	10µF	Tantalum 10V
C7	Capacitor	10µF	Tantalum 10V
C8	Capacitor	10µF	Tantalum 10V
C9	Capacitor	0.1µF	Tantalum 10V
C10	Capacitor	0.1µF	Tantalum 10V
C11	Capacitor	0.1µF	Tantalum 10V
C12	Capacitor	10µF	Tantalum 16V
C13	Capacitor	10µF	Tantalum 16V
C14	Capacitor	10µF	Tantalum 16V
C15	Capacitor	100nF	
C16	Capacitor	1nF	Feed-Through
C17	Capacitor	100nF	
C18	Capacitor	1nF	Feed-Through
C19	Capacitor	100nF	
C20	Capacitor	1nF	Feed-Through
D1	Diode	ZD16	Zener
D2	Diode	ZD4.7	Zener
IC1	Voltage Regulator	LT1084	Low Drop TO247
IC2	Voltage Regulator	78L06	TO92
IC3	DC-DC Converter	ICL7660	DIL8
P1	Potentiometer	2.5kΩ (2kΩ)	Piher/Cermet
P2	Potentiometer	2.5kΩ (2kΩ)	Piher/Cermet
P3	Potentiometer	2.5kΩ (2kΩ)	Piher/Cermet
R1	Resistor	2kΩ (22K ∥ 2.2K)	Metal Film
R2	Resistor	270Ω	Metal Film
R3	Resistor	10kΩ	Metal Film
R4	Resistor	470Ω	Metal Film
R5	Resistor	470Ω	Metal Film
R6	Resistor	470	Metal Film
R7	Resistor	470Ω	SMD
R8	Resistor	470Ω	SMD
R9	Resistor	470Ω	SMD
R10	Resistor	3Ω / 1.5W	Metal Film (3 x 10Ω)
R11	Resistor	0.5Ω / 1W	Metal Film (2 x 1Ω)
R12	Resistor	0.5Ω / 1W	Metal Film (2 x 1Ω)
T1	Transistor	BC546B	NPN TO92

+5 1nF Feed-Through Capacitors for PSU from UG3 and LT1084, (see Fig.5)

Fig.8: PSU Parts List

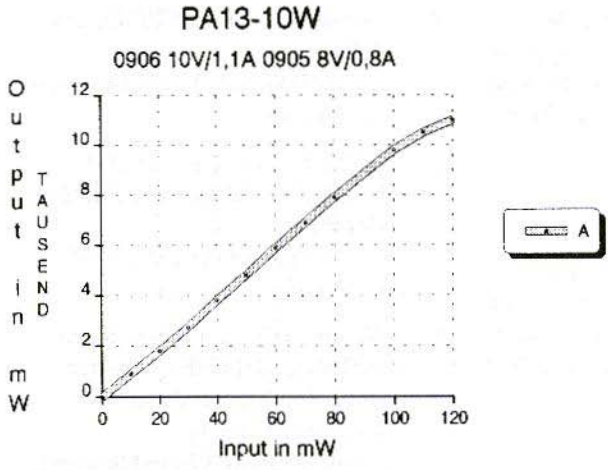


Fig.9: Transfer Characteristic for 10W PA

further increase in power leads to a considerable reduction in the intermodulation interval and thus to signal distortion in linear mode.

Fig.10 shows the gain slope measured by means of an HP 8690B sweeper with 8699B at an input power of 50 mW and plotted against the frequency.

Here curve A shows the slope measured for an amplifier tuned to 2,320 MHz. Curve B shows the slope in a simulation of S21, as per Fig.1. The amplifier consequently has a power band width of over 100 MHz. Its amplification drop to the limit frequencies is, of course, somewhat greater than in Curve B. The linear amplification of 20 dB attained deviates only slightly from the calculated values.

This amplifier can be used in the ATV range at 2,380 MHz - with rather less amplification for the same output power, of course. The author therefore developed an amplifier specially de-

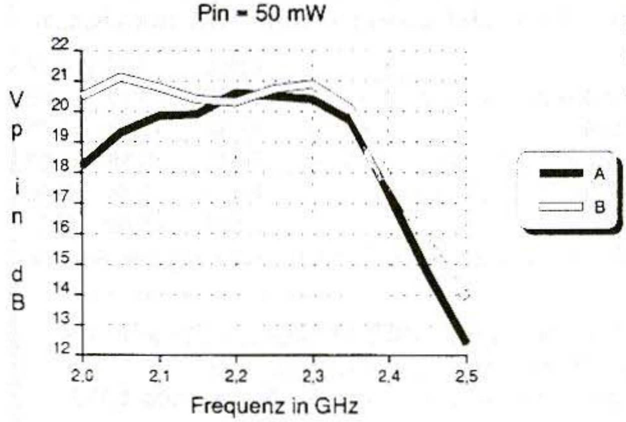


Fig.10: Gain Slope plotted against Frequency

signed for the ATV range, with a maximum amplification level app. 80 MHz higher. Another article in the near future will give details of the layout and the readings obtained.

Note: *The PUFF CAD software package used in this project is available from KM Publications at the usual address. The price of the software at the time of publication of this article is £20.00 plus shipping at cost.*

5. LITERATURE

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